RFP No. RCI-2-32049

STATEMENT OF WORK

"Next Generation Natural Gas Vehicle (NGNGV) Phase II: Vehicle Integration Projects"

04/22/02

Introduction and Background

The U.S. Department of Energy has identified the development of the next-generation natural gas vehicle program (NGNGV) as a strategic element in its plan to reduce oil imports and vehicle pollutants. Natural gas is a clean-burning, abundant, domestically available fossil fuel that many consider the fuel of choice for the transition to a more sustainable energy future. Although DOE is "fuel neutral", it considers natural gas (in both compressed and liquefied forms) to be a promising vehicle fuel in terms of cost competitiveness, domestic sources, vehicle performance, and low emissions of criteria pollutants.

DOE has selected the National Renewable Energy Laboratory (NREL) to lead the effort to develop commercially viable medium-duty and heavy-duty natural gas vehicles (NGVs) to help nonattainment areas reduce pollutant emissions. The vision is to develop new medium-duty (Class 3-6) compressed natural gas (CNG) and new heavy (Class 7-8) liquefied natural gas (LNG) vehicles that will be available as early as 2004 to help nonattainment areas reduce criteria pollutants from vehicles. Medium and heavy duty NGVs are available today; however, the goal is to help advance the technology and the vehicles by commercially implementing DOE-supported advanced technologies, including advanced natural gas engines, new materials and enhanced natural gas fuel storage. Emission standards for the 2004 model year for these vehicle classes are lowering significantly. In order to remain competitive in the marketplace, NGVs must not only meet these standards, but exceed them, thereby being cleaner than other heavy duty and medium duty vehicles, earning credits and qualifying for purchase incentives. The program's goal for these new vehicles is to have oxides of nitrogen (NO_x) emissions at or below 0.5 g/bhp-hr and particulate matter (PM) emissions at or below 0.01 g/bhp-hr, which represent a significant step-change in NGV technology. Perhaps the most ambitious goal is that these next-generation vehicles should be fully competitive—technically and commercially viable—with their conventionally fueled vehicle counterparts.

Objective

The objectives of this project are to:

(1) Demonstrate technologies and methods for controlling emissions of natural gas engines, including technologies such as advanced combustion, emission control and/or after treatment devices to achieve 0.5 g/bhp-hr or lower NOx emissions and 0.01 g/bhp-hr PM emissions, and be capable of certification to 2004 Environmental Protection Agency (EPA) standards, while targeting to maintain efficiency and/or fuel economy of currently available natural gas engines;

(2) Fully integrate advanced technology engines into commercially viable chassis applications;

(3) Complete the development of heavy duty (HD) or medium duty (MD) vehicles in real world, on road, fleet applications; and

(4) Commercialize the vehicle.

Fuel economy, performance, operating costs and commercial marketability of a vehicle platform are all integral parts of the ultimate success of a new product. Addressing all challenges to natural gas engine development and vehicle integration and operation, as well as fully demonstrating market feasibility, are the emphases of this project.

Scope of Work Overview

This project is intended to develop a commercially viable medium duty (CNG) or heavy duty liquid natural gas (LNG) vehicle, and consists of four separate tasks.

Task 1 addresses the development and optimization of a natural gas internal combustion engine. In order to make the product of interest in the marketplace, the engine must be capable of NOx emissions of 0.5g/bhp-hr NOx and 0.01g/bhp-hr PM or lower, as well as meeting 2004 EPA requirements. These emission targets would give the final product a market advantage by allowing manufacturers to earn emission credits for its sale and allowing customers to receive vehicle incentives under various incentive programs, such as the Carl Moyer Program in California. This will also potentially give the subcontractor the opportunity to learn what will be needed to meet the more stringent 2007 EPA NOx standards.

The engine development may include hardware and software enhancements as well as aftertreatment, and shall target efficiency of currently available medium duty or heavy duty natural gas engines with comparable or improved performance. Special consideration shall also be made in Task 1 to ensure that the engine selected can be integrated into a chassis platform that is commercially desirable. *Note that if a transit bus application is selected, the engine must also satisfy the 0.01g/bhp-hr formaldehyde standard. For all other applications, the lowest formaldehyde levels are encouraged..*

Task 2 involves the full integration of the low NOx engine into a chassis that is commercially viable. This task requires working through all the challenges associated with the integration of the engine into the selected platform, including installation of the engine into the chassis, integration with the vehicle fuel system, drive line matching, and other activities as necessary. The subcontractor must ensure that the performance of the final product will be commercially acceptable for the chosen application.

Task 3 includes the on-road development and demonstration of the integrated vehicle. This requires the subcontractor to work closely with a fleet or fleets to identify a good application for the vehicle and to conduct on-road testing of these vehicles during the standard operations of the fleet. Fleets shall be selected that are willing to keep good records of vehicle driving patterns, refueling patterns, and performance issues to thoroughly document performance and operating costs for vehicles. The subcontractor will work closely with the fleet(s) during this period to ensure further development and enhancement of the engineand vehicle. The purpose of this task is twofold: 1) to continue to refine the engine/vehicle integration, and 2) to collect data to evaluate actual vehicle performance.

Optional Task 4 is the final certification of the product with the Environmental Protection Agency (EPA) or the California Air Resources Board (ARB). Because care was taken to select a commercially viable product, and laboratory and on-road development were used to develop the product, the next logical step is certification, so that the product could be sold to medium duty or heavy duty customers. This task is optional, to be negotiated between NREL and the subcontractor, and could occur at any point during the period of performance, not necessarily as the final task.

Tasks

The overall outcome of this project will be the full integration of an optimized medium duty CNG engine or heavy duty LNG engine into a commercially viable chassis. The task descriptions are as follows.

Task 1: Engine Development
Subcontractor will optimize the medium duty CNG or heavy duty LNG engine to reduce emissions to 0.5g/ghp-hr NOx and 0.01g/bhp-hr PM, and 2004 EPA standards on the Federal Test Procedure (FTP) and perform well under real world, on road conditions, while maintaining efficiency and/or fuel economy of currently available natural gas engines. *Note that if a transit bus application is selected, the engine must also satisfy the 0.01g/bhp-hr formaldehyde standard.*

The purpose of Task 1 is not only to optimize a heavy duty or medium duty engine, but to do so with the goal of integration into a commercially desirable chassis style. The selected engine shall be optimized to demonstrate technology options for reducing emissions from natural gas engines, including aftertreatment, while maintaining or enhancing efficiency under real world conditions. Specific strategies may include, and are not limited to: aftertreatment development, fuel system optimization, electronic control strategy development, and/or sensor development. The results of this task will include the technical details of the optimization strategies used, and an engine developed and ready for vehicle integration, and capable of demonstrating the required emission capability.

Task 2: Vehicle Integration
Subcontractor will fully integrate optimized natural gas engine into the chosen platform.

A prime objective of the NGNGV program is to not only advance new technology, but also to promote the successful deployment of this technology. The vehicles resulting from this task must meet fleet customer needs and performance requirements ad identified from the business plan, based upon the selected vehicle platform, and in coordination with the fleet operator(s) selected for Task 3. The vehicle shall also meet all SAE standards applicable to CNG/LNG fuel system vehicles, such as J2342 and J2406. The outcomes of this task are the technical details of the integration process and an integrated vehicle ready for on road demonstration. Specific subtasks may include, and are not limited to:

- Fuel system integration,
- Cooling system modifications,
- Control strategy modifications.

Task 3: Engine and Vehicle Development and Demonstration
Subcontractor will incorporate the integrated vehicle into a revenue fleet to test and to collect data for a minimum of six months of operation.

The subcontractor will identify a fleet or fleets to assist them with the on-road development and refinement of the integrated vehicle. The subcontractor will ensure that control vehicles are identified and tracked within the fleet to compare the performance of the test vehicles to the regular vehicles in the fleet. The identified fleet must understand that the purpose of the task is to prove out the vehicle and to work through any technical, mechanical, or logistical issues that arise as a result of the engine development and integration. In addition, the subcontractor must ensure that the fleet operator is willing and able to maintain good records related to vehicle usage. The subcontractor and fleet operator shall document all maintenance, oil change intervals, refueling, mileage accumulation and duty cycle information during the duration of the demonstration. The subcontractor must ensure that the fleet operator is willing to participate fully through detailed record keeping and frequent usage of all of the vehicles. In addition to the fleet demonstration, further demonstration will be conducted on these vehicles by chassis testing them on the West Virginia University dynamometer. The subcontractor shall make all vehicles available to NREL at the completion of the fleet demonstration for this testing. Specific scheduling regarding this testing will be worked out between NREL and the subcontractor.

The results of this task include a fully developed, integrated vehicle, with documented vehicle maintenance information, and operating cost information. At the conclusion of Task 3 the subcontractor shall supply the following information on the configurations:

- Duty cycle information;
- Data collection methods;
- Refueling and maintenance records;
- Final development vehicle specifications
    - Final engine specs: horsepower and torque curves, efficiency map, FTP emission test data, Brake specific fuel consumption over FTP
    - Final vehicle specs: GVWR, chassis type, transmission, aftertreatment)
- Control vehicle specifications (engine size, horsepower, torque, GVWR, chassis type, transmission, aftertreatment);
- The complete data set in the format shown in Attachment #1

Task 4: Certification (Optional)
Subcontractor will prepare and submit all paperwork required for full certification and sale of the integrated vehicle and/or engine.

The subcontractor shall identify the appropriate time and the best engine configuration for emission testing and commercialization. The engine configuration shall be capable of demonstrating the project technical objectives of 0.5g/bhp-hr NOx and 0.010g/bhp-hr PM (but may be certified to a higher level, as mutually agreed upon between NREL and the subcontractor), and have commercial viability. The subcontractor shall arrange for the engine to be tested in accord with the heavy-duty FTP, 40 CFR Part 86, subpart N.

Review Meetings
The following review meetings will be required and specific timing will be coordinated between NREL and the subcontractor.

1. Interim Project Review (1 year or halfway point) – to present the project implementation plan, vehicle and engine selection and integration process, and preliminary on-road

demonstration plan. Participants in the meeting shall include the subcontractor's team members, NREL, DOE, state agencies interested in the project, and, as determined appropriate by the NREL Technical Monitor, other stakeholders or potential customers for the vehicle.

2. Conference Presentation or Steering Committee Presentations – to provide an overview of the project status and/or results, depending on timing of these reviews. They will take place during the subcontract period of performance and may include presentations at NGNGV meetings or technical conferences. There may be up to two such presentations.

3. Final Project Review – to be held before the end of the period of performance of the subcontract to provide a summary of activities and results. Participants in the meeting shall include the subcontractor's team members, and may include NREL, DOE, state agencies interested in the project, and, as determined appropriate by the NREL Technical Monitor, other stakeholders or potential customers for the vehicle.

Deliverables

The Subcontractor must provide detailed project deliverables to demonstrate successful and thorough completion of requirements, and keep NREL apprised of project progress. The subcontractor shall not publish or present any results from this project without approval from NREL.

1. *Engine Development Milestone Report* – This report(s) shall contain summaries of activities, technical details, schematics, and specific data where applicable, in addition to the updated project Gantt chart. There may be multiple milestone reports for the engine development task, based upon the milestones shown on the Gantt chart and agreed upon by NREL and the subcontractor (due at the completion of identified milestones). All milestone reports should be delivered in Microsoft Word format. Specific schematics or technical information may be delivered in paper format to supplement the report if it is more convenient. The report(s) from this task shall include, but are not limited to:

    - Preliminary emission results;
    - Brake specific fuel consumption;
    - Engine performance data (horsepower, torque);
    - Description of engine (displacement);
    - Engine fuel system diagrams;
    - Methodology used;
    - Description of aftertreatment
    - Applicable high-resolution digital photographs;
    - Updated Gantt chart.

2. *Vehicle Integration Milestone Report* – This report(s) shall contain summaries of activities, technical details, schematics, high resolution digital photographs, and specific data where applicable, in addition to the updated project Gantt chart. There may be multiple milestone reports for the vehicle integration task, based upon the milestones shown on the Gantt chart and agreed upon by NREL and the subcontractor (due at the completion of identified milestones). All milestone reports should be delivered in Microsoft Word format. Specific schematics or technical information may be delivered in

paper format to supplement the report if it is more convenient. The report(s) from this task shall include, but are not limited to:

- Vehicle specification sheet (engine size, horsepower, torque, chassis type, GVWR, transmission, etc);
- Fuel system, cooling system, etc. integration activities and diagrams;
- Control strategy integration activities;
- Applicable high-resolution digital photographs;
- Updated Gantt chart.

3. *Engine and Vehicle Development and Demonstration Milestone Report* – This report(s) shall contain summaries of activities, technical details, and specific data where applicable, in addition to the updated project Gantt chart. There may be multiple milestone reports for the fleet demonstration and development task, based upon the milestones shown on the Gantt chart and agreed upon by NREL and the subcontractor (due at the completion of identified milestones). All milestone reports should be delivered in Microsoft Word format. Specific schematics or technical information may be delivered in paper format to supplement the report if it is more convenient. The report(s) from this task shall include, but are not limited to:

    - Control vehicle specifications (engine size, horsepower, torque, GVWR, chassis type, transmission, aftertreatment);
    - Duty cycle information;
    - Data collection methods;
    - Refueling and maintenance records;
    - Final development vehicle specifications (engine size, horsepower, torque, GVWR, chassis type, transmission, aftertreatment);
    - Applicable high-resolution digital photographs;
    - Complete data set in the format shown in Attachment #1;
    - Updated Gantt chart.

4. *Certification Milestone Report* – This report(s) shall contain summaries of activities, technical details, and specific data where applicable, in addition to the updated project Gantt chart. There may be multiple milestone reports for the certification task, based upon the milestones shown on the Gantt chart and agreed upon by NREL and the subcontractor (due at the completion of identified milestones). All milestone reports shall be delivered in Microsoft Word format. Specific schematics or technical information may be delivered in paper format to supplement the report as agreed to by the Technical Monitor.

5. *Project Final Report* - A draft final report will be submitted to NREL within 30 days of completion of all project tasks in Microsoft Word 6.0 format. NREL will review the report within two weeks and provide feedback to the subcontractor. The subcontractor will then have fifteen (15) days to make updates and submit the final version of the report. The final report shall be provided to NREL in hard copy and in Microsoft Word format. The final report will consist of a summary of data collected and reported in each milestone report above, including the following elements:

    - A technical description that will include all systems affected by proposed technology;

- A description of data acquisition, test protocol, and fuel used during performance evaluation;
- Performance evaluation data;
- Fuel system diagrams;
- Data reduction and analysis of all data;
- Applicable high resolution digital photographs;
- Hardware cost estimate which includes system modifications, as necessary;
- Hardware/system availability date estimate (date by which prototypes could be available for on-road prototype testing).

Note: If segregation of proprietary data is required, the subcontractor may prepare two versions of a report, one with the full technical detail as required by this deliverable and a public version with sensitive data omitted.

6. *SAE Paper and Presentation* – An SAE Paper abstract, paper, and possibly a presentation, shall be developed for the 2004 SAE Truck and Bus meeting to highlight the significant activities and results achieved under this subcontract. The subcontractor shall provide NREL with electronic copies of all presentation materials.

7. *Meetings* – Meetings, as described in Section 5 of this Statement of Work, will be required. These meetings will be scheduled by NREL, with concurrence of the subcontractor, when appropriate throughout the duration of this subcontract.

Electronic and hard copies of the stated deliverables shall be sent to the following addressees:

One hard copy of all deliverables shall be submitted to:

Subcontract Associate -- TBD
National Renewable Energy Laboratory
1617 Cole Blvd.
Golden, CO 80401-3393

Electronic files, and hard copies as requested, shall be submitted to:
Technical Monitor -- TBD
Center for Transportation Technologies and Systems
National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, CO 80401

Attachment #1

VEHICLE SPECIFICATIONS

Revised 1/12/96

HDV_VEH Table

Vehicle ID Number (VIN)	Vehicle identification number	
Fleet_Veh_ID	Vehicle identification number used by fleet	
Vehicle_Make	Name of vehicle manufacturer	
Vehicle_Model	Truck model number	
Vehicle_Year	Year vehicle was manufactured	
Service_Date	Date vehicle was put into service by fleet	
Start_Mileage	Mileage on vehicle at the start of the fleet demonstration	
Activity_Code	Type of activity vehicle is used for (Code 1 from VMRSH)	
Equipment_Category_Code	Type of optional equipment installed on vehicle	
Body_Mfgr_Code	Name of body manufacturer	
Body_Descr_Code	Type of body attached to cab (Code 48 from VMRSH)	
Engine_Serial	Serial number of the engine	

HDV_ENGINE Table

OEM_Retrofit	Is the engine OEM or a retrofit?	
Eng_Mfgr_Code	Name of engine manufacturer	
Eng_Model	Engine model number	
Eng_Config_Code	Engine Configuration Code (Code 35 from VMRSH)	
Eng_Cu_In	Engine size in cubic inches	
Num_Cylinders	Number of cylinders	
Eng_Year	Year engine was manufactured	

Cycle	Is the engine 2 cycle or 4 cycle ?	
Compr_Ratio	Compression ratio	
Ignition_Aid_Type	Type of ignition aids used	
EPA Certified (Y/N)	Is the engine configuration EPA certified	
Maximum bHp	Rated maximum brake horsepower of engine	
Rpm of Max bHp	Rpm at rated maximum brake horsepower	
Maximum Torque (ft-lbs)	Rated maximum torque of engine	
Rpm of Max Torque	Rpm at rated maximum torque	
Oil Capacity (qts)	Oil capacity in quarts	
Blower? (Y/N)	Does the engine have a blower?	
Turbocharger? (Y/N)	Does the engine have a turbocharger?	

HDV_FUEL_SYSTEMS
Table

Fuel_ Type_Code	What type of fuel is engine designed for?	
Diesel Additives	Type of additives used in diesel fuel	
Alt Fuel Additives	Type of additives used in alternative fuel	
Mech_Elec	For liquid fuel engines, are the injectors mechanically or electronically controlled?	
Injector Mfr	Name of liquid fuel injector manufacturer	
Inj Model	Liquid fuel injector model number	
Num of Injectors	Number of liquid fuel injectors	
Liq-Fuel Filter Mfr	Name of liquid fuel filter manufacturer	
Liq-Fuel Filter Model	Liquid fuel filter model number	
Fuel_Induction	For gaseous fuel engines, is it injection or fumigation?	
Air Intake Throttle (Y/N)	Does the engine use an air intake throttle	
Gas Equip (OEM/Retrofit)	Is the gas fuel system OEM or retrofit?	
Number of Alt Fuel Tanks	Number of alternative fuel tanks	
Number of Diesel Tanks	Number of diesel tanks	

AF Max Work Press (psi)	Alternative fuel maximum working pressure in psi	
Amount of Useable AF	Total useful alternative fuel in tank(s)	
Alt Fuel Units	Units used for alternative fuel tank(s) useful volume	
Amount of Useable Diesel	Total useful diesel fuel in tank(s)	
Diesel Fuel Units	Units used for diesel fuel tank(s) useful volume	
AF Tank Manufacturer	Name of alternative fuel tank(s) manufacturer	
Diesel Tank Manufacturer	Name of diesel fuel tank(s) manufacturer	
Alt Fuel Tank Model	Alternative fuel tank(s) model number	
Diesel Tank Model	Diesel fuel tank(s) model number	
Alt Fuel Empty Tank Wt	Alternative fuel tank(s) empty weight	
Alt Fuel Tank Wt Units	Units used for alternative fuel tank(s) empty weight	
Diesel Empty Tank Wt	Diesel fuel tank(s) empty weight	
Diesel Tank Wt Units	Units used for diesel fuel tank(s) empty weight	

HDV_TRANS Table

Transmission Mfr	Name of transmission manufacturer	
Trans Model Number	Transmission model number	
Trans Year of Mfr	Transmission year of manufacture	
Trans_Type_Code	Type of Transmission (Code 7 from VMRSH)	
Forward Speeds	Number of forward speeds	
Reverse_Speeds	Number of reverse speeds	

HDV_AXLE Table

Axle_Type_Code	Type of axle configuration (Code 3 from VMRSH)	

Axle_Front_Weight	Axle front weight	
Front_Tire_Size	Size of front tire	
Rear_Tire_Size	Size of rear tires	
Axle_Mfgr_Code	Name of drive axle manufacturer (from VMRSH)	
Axle Model	Drive axle model number	
Rear_Axle_Config_Code	Rear axle configuration (Code 37 from VMRSH)	
Rear_Axle_Setup_Code	Setup of rear axle configuration (Code 38 from VMRSH)	
Axle_Ratio_Low	Low axle ratio	
Axle_Ratio_High	High axle ratio	
Total GVW Wt (lb)	Total gross vehicle weight in pounds	
Total Curb Wt (lb)	Total weight with the truck in curb weight configuration	
Torque Converter Ratio	Torque converter ratio	
Wheelbase	Length of wheelbase	

HDV_EMISSION Table

Cat_Conv	Does the vehicle have a catalytic converter? Y or N	
Cat_Conv_Mfg	Name of catalytic converter manufacturer.	
Cat_Conv_Model	Model number of the catalytic converter.	
Dsl_Prt_Trap	Does the vehicle have a diesel particulate trap? Y or N	
Trap_Mfg	Name of the particulate trap manufacturer.	
Trap_Model	Model number of the particulate trap.	
Trap_Regen_Type	Type of trap regeneration process	
Trap_Conf	Particulate trap configuration	
Num_Trap_Ele	Number of particulate trap elements	
Trap_Sys_Wt	Weight of the particulate trap system	